A Brief Review of Hydraulic Pump Operation

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PUMPING SYSTEMS

The term "hydraulic pumping system" as used herein, is taken to mean a particular method of lifting fluid from oil reservoirs, in which a power pump, distribution lines, subsurface pumps, and other auxiliary components are employed. Some of the most familiar manufacturers of this type of pumping equipment are Kobe, Inc., Sargent Engineering Corporation, and National Supply Company.

Sometimes this system is referred to as "hydraulic rodless pumping", but in the strictest sense this is untrue because there is always a rod connecting the engine and pump pistons. However, sucker rods are not required in this mechanical reciprocating pump, which may have contributed to this system being termed "rodless".

It is very difficult to compare one pumping method with another unless the comparison is restircted to specific applications. All factors should be accounted for, such as expected average depth of lift, daily volume of fluid to be lifted, specific gravity of fluid to be lifted, investment cost, operating cost, characteristics of operation, operational difficulties expected, expected life of operation, nature of produced fluids, well spacing program, vertical deviation of the well bore, reservoir and well bore conditions and many other factors. Once the conditions are set, the comparison of one system of pumping with another is greatly simplified.

Many types of artificial lift systems are used in the West Texas-New Mexico area. Perhaps the most common is the beam unit. It will be convenient, therefore, to compare the hydraulic pumping system with the beam unit method.

Hydraulic Pumping System

There are several component parts in the hydraulic pumping system, each designed to perform a specific function. There is a power oil tank which is a large reservoir providing settling time to accomplish a certain amount of gravity segregation. There is a power pump, commonly a triplex, which simply takes oil from the power oil tank at atmospheric pressure and adds presure to the oil usually up to a maximum of 5000 pounds per square inch.

The power pump must be capable of furnishing oil to the subsurface pumps at the pressure and rate required. The pressure required at the power pump discharge is governed by bottom-hole pump size, well conditions, and friction losses in the surface and subsurface lines and equipment.

If the lift system contains more than one well, it is necessary to provide a method of distributing oil to individual wells. This is accomplished with a central power control which is simply a grouping of valves, fittings, pressure gauges and meters. From this point, oil is transmitted to wells through surface power oil lines.

At the wellhead, power oil is routed down tubing by means of a quickacting head if the bottom-hole pump is of the conventional type, or a four-way valve if of the free type. High pressure power oil is introduced into the bottom-hole pump, then exhausted and commingled with produced fluids. Exhausted power oil and fluids produced from the well are moved to the surface and through flow lines to the tank battery. There is usually justification for some type of treating system in a hydraulic pumping operation. From here, oil is returned to the power oil tank, which is the point of origin.

Net formation oil production is removed from the power oil tank by means of a line so located that it can never by itself lower the level in the power oil tank below the top triplex suction line. Accounting for daily oil production then is a simple matter. The only error possible would be a small daily variation in the power oil tank liquid level which could be accurately accounted for by gauging the power oil tank.

The preceding is a very brief description of the components of a hydraulic pumping system. It should be expected that many variations will be found in operation.

Reasons for Use

As compared to a sucker rod pump operated by a beam unit, the hydraulic system may appear to be unduly complicated and one may very well question why it is used. There are many reasons for its use. Some are listed as follows:

1. Compared to sucker rod pumps, this system is usually capable of lifting a larger daily fluid volume.
2. No sucker rods are used; thus the ordinary difficulties associated with sucker rods are elimated.
3. Wells may be grouped and operated from a central point which might eliminate frequent trips to individual wells.
4. The bottom-hole pump may be operated over a fairly wide speed range, resulting in greater flexibility for controlling daily producing rate than sucker rod pumps.
5. This equipment can be used in crooked holes, whereas sucker rods would be undesirable because of excessive rod and tubing wear.
6. Power pumps may be added or removed as determined by pumping requirements, or bottom-hole pump sizes can be changed without a significant equipment replacement. This greatly increases the flexibility of operation as compared to individual pumping units.
7. The operating or working fluid level may be estimated by using pressure gauge readings. This provides a quick check for well condition.
8. In multiple well systems, the per well investment for lift equipment is usually less in the hydraulic system.
9. Paraffin removal is somewhat simpler in this compared to other methods.
10. Pump pulling costs are virtually eliminated when the free-type pump is used because it can be surfaced by reversing power oil flow into the well.

The familiar beam pump may, in many instances, provide a highly satisfactory method of lifting oil. If conditions are right, it may surpass all other types of artificial lift in terms of reliability, simplicity of operational characteristics and long term cost of operation. However, the same is usually true of the hydraulic pumping system if the following conditions are met:

1. The pumping conditions must be suitable for hydraulic operation. It would not be desirable to install a hydraulic pump in a reservoir producing extremely viscous fluids which would require excessive surface pressure to overcome fluid friction and would result in high power costs.
2. Operating personnel should be trained to operate the equipment properly. This is one of the greatest obstacles facing hydraulic pumping.
3. Preventive maintenance is very important. Small difficulties have a habit of growing larger if not corrected early.

In a manner of speaking, the power pump, power oil tank, lines, etc. are only accessories to the bottom-hole pump. These "accessories" are necessary to provide a power supply. The heart of the hydraulic system is the bottom-hole pump.

As stated previously, several manufacturers market hydraulic pumps. Kobe is probably in wider use in the West Texas-New Mexico area than any other pump, although Sargent has increased its sales effort in the past two years, and National has done a limited amount of marketing in selected areas. Dempsey pumps are popular in other areas, and Fluid Pack has only recently developed and placed a hydraulic pump on the market. Since the basic operating principal of all subsurface hydraulic pumps is similar, the operational features of the Kobe pump only will be described.

The Kobe Pump

The Kobe pump is very similar in operation to a single cylinder, double-acting steam engine driving a duplex pump. That is, each half stroke of the engine piston is a power stroke, and each half stroke of the pump piston is a production stroke. High pressure power oil is alternately admitted to first one end of the engine piston, then to the other. This causes the engine piston to move up or down. The entry of oil into the engine piston is controlled by an hydraulically operated engine valve.

While oil is being admitted to one end of the engine piston, the engine valve releases exhaust power oil from the other end and it is commingled with produced fluid, then moved to the surface. As long as the production tubing is full there will be no power expenditure in returning the exhaust power oil to the surface since the static head of the exhaust power oil is balanced by the static head of the high pressure power oil. The work done by the subsurface pump is limited to lifting the produced fluid and overcoming fluid friction.

The engine piston is connected to the pump piston by means of a rod; therefore, the motion of the engine is imparted exactly to the pump. The rod is short and rigid and the engine piston and pump piston stroke lengths are the same for all practical purposes. The pump end of a Kobe production unit is very similar to the engine end. There is a system of intake and discharge valves to control fluid flow through the pump.

On the upstroke the upper intake valve will be closed and the discharge valve open so that fluid will be discharged into the production column. At the same time, the lower intake valve will be open and the discharge valve closed so that the lower end of the pump is filled with well fluid.

On the downstroke, the valves and action are reversed. This results in pump displacement on each up or down movement of the pump piston, and on a full stroke basis, the pump is said to be double acting. The intake and discharge valves on the pump end are balls and seats and are arranged so fluid can pass in only one direction. This is necessary to prevent circulation around the pump. All the valves on the pump end operate on differential pressure.

At each end of the stroke, the engine valve will actually cut off all power oil flow into the engine. Of course, this is of only a momentary nature, but is sufficiently long that an increase in pressure will be noted on a surface pressure gauge. Counting strokes of a Kobe pump is relatively easy after a demonstration and a little practice. A half stroke is defined as the movement of the pump from top to bottom, which would be the downstroke, or from bottom to top, the upstroke.

Since oil flow is momentarily stopped at each change of pump direction, counting strokes becomes a matter of observing a surface pressure gauge and counting pressure gauge fluctuations. Assume that a pressure gauge is operating, fluctuating between 2000 and 2300 psi. Pick either 2000 or 2300, but be consistent. Watch the gauge and each time the gauge reads 2000 or 2300, whichever is selected, count 1, 2, 3, etc. Starting at zero time and continuing for exactly 30 seconds will result in strokes per minute, since half strokes were counted for half a minute.

Sometimes it is difficult to count strokes because of triplex vibration. This vibration can be reduced by holding an object weighing a pound or so to the back of the pressure gauge to absorb and dampen the vibrations. The vibrations can be practically eliminated by mounting the pressure gauges on a board fixed to the ground and using flexible hoses to connect the gauges to the pressure connection on the control station. It also helps if the power oil line from the triplex discharge assembly loops the control station before being connected to the feeder manifold. This absorbs and dampens out a great deal of triplex vibration.

If the pressure gauge is not working or strokes cannot be counted for any reason, an estimate can be made using power oil input readings. From the power oil meter, the total barrels per day of input power oil can be estimated. If this figure is divided by the barrels per day per stroke per minute rating of the engine and of the production unit, strokes per minute will result. The calculated value will be at 100 percent efficiency. If the average engine efficiency is known, a fairly realistic calculated strokes per minute will be obtained.

Evaluating the efficiency of an hydraulic pump is fairly simple as compared to sucker rod pumps. Since there are no sucker rods in an hydraulic pumping system, there is no stretch to calculate, and the rated stroke length, for all practical purposes, is the actual stroke length. Since the volume displacement is a measured value per stroke, and strokes per minute can be counted, actual production can be measured from which a pump volumetric efficiency can easily be calculated.

Almost everyone is familiar with the long calculations involved in estimating the net stroke of a sucker rod pump. This is a tedious calculation and must be redone each time the polished rod stroke or pumping speed is changed. With the hydraulic pump, it is necessary only to make measurements to obtain the necessary data.

Testing Wells

Testing wells lifted by the use of hydraulic pumps is somewhat different than testing wells lifted by other methods. If a single well is operated by a triplex pump, the net production is a spillover from the power oil tank to stock.

If several wells are operated by a triplex and it is desired to test one well, all wells except the test well could be shut in, reducing the system, in effect, to a single well. This procedure may be undesirable because daily production could be lost. This possibility can be overcome by diverting the test well production through a test separator, then to separate tankage, or through an oil meter run. Since the volume put into a separate tank or meter run includes the power oil used to lift the produced volume, it is necessary to subtract the power oil from the total oil measured to obtain the produced oil volume. If separate tankage is used, the amount of power oil used to pump the test well will not be returned to the power oil tank, and this volume must be kept in mind.

Assume, for example, that an hydraulic system has four connected wells, each requiring 150 barrels of power oil per day for an average per well production of 30 barrels per day. The test well would draw the power oil tank down 150 barrels, the three remaining wells could produce only 90 net barrels and therefore, the net power oil tank drawdown would be 60 barrels. Depending on the level in the power oil tank when the test was started, it would be possible to reduce the level to such an extent that the suction line would run dry, starve the triplex and damage it. This difficulty can be overcome by drawing oil from a tank other than the test tank and circulating into the power oil tank.

Another test procedure would be to use a portable test separator such as a Rolo Well Checker. Test connections can be located in flow lines or at the production header so that the power oil and produced fluids can be measured, then put back into the system for routing into the power oil tank. If ordinary shakeouts are used to determine water production, it must be remembered that the water percentage indicated by the centrifuge tubes is relative to the power oil plus produced fluid volume. Appropriate corrections must be made to relate the produced water to the produced fluid.

While testing a well for producing ability, it is a simple matter to record the information necessary for calculating hydraulic pumping efficiency. The following records are desirable:

1. Identification of well,
2. Date and time test starts and ends,
3. Last stroke pressure at beginning and end of test.
4. Operating pressure at beginning and end of test,
5. Pump strokes per minute at beginning and end of test,
6. Power oil meter readings at beginning and end of test,
7. Tank gauge or meter readings at beginning and end of test, and
8. Shakeout or water production data.

For ordinary day-to-day pumping, a record of the following would be invaluable in well condition and pumping equipment analysis:

1. Daily power oil meter readings,
2. Daily operating pressures, and
3. Daily pump speeds.

With this information and the daily production reports, efficiency losses can be noted quickly so that if additional tests are required, they can be taken and remedial action performed before much loss in production occurs. It would be beneficial to record last stroke pressures periodically.

The last stroke pressure is obtained by shutting in the block valve on the power oil line to the well and noting the pressure gauge readings as the pump slows down. When the pump stops stroking, that pressure is the last stroke pressure. At the last stroke pressure, fluid and mechanical friction becomes zero for all practical purposes, and with this information and pump specifications, a working fluid level can be calculated for the well.

With respect to hydraulic pumping, there are only three principal things over which a pumper has either partial or complete control. These are:

1. Pump speed control,
2. Paraffin control, and
3. Power oil rate and quality control.

One of the most important single requirements in hydraulic pumping is an adequate supply of clean power oil. This does not mean power oil of simply pipeline quality, which might not be good enough. It does mean oil free of entrained abrasive particles which would cause undue wear on the moving parts, or nonabrasive materials which would screen out in the small openings and block flow through the engine of the subsurface pump. If these items are properly attended to so that the manufacturer's specifications and design limitations are adhered to, hydraulic pumping operations will become much more successful.